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Request for grant of a patent

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1. Your reference — P3173 GB PRO

2. Patent application number *(The Patent Office will fill this part in)* — 0323068.7 — 01 OCT 2003

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

NUGROUND LIMITED
NANNOTECHNOLOGY CENTRE
HERSCHEL BUILDING
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NEWCASTLE UPON TYNE NE1 7RU
UNITED KINGDOM

Patents ADP number *(if you know it)* — 08726085001

If the applicant is a corporate body, give the country/state of its incorporation — UNITED KINGDOM

4. Title of the invention — DEWATERING TREATMENT SYSTEM AND METHOD

5. Name of your agent *(if you have one)* — NOVAGRAAF PATENTS LIMITED

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

THE CRESCENT
54 BLOSSOM STREET
YORK YO24 1AP

Patents ADP number *(if you know it)* — 08299166001

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. Divisionals, etc: Complete this section only if this application is a divisional application or resulted from an entitlement dispute (see note f)

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Answer YES if:
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Continuation sheets of this form	
Description	17
Claim(s)	CF
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Translations of priority documents	
Statement of inventorship and right to grant of a patent (Patents Form 7/77)	
Request for a preliminary examination and search (Patents Form 9/77)	
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Any other documents (please specify)	

11. I/We request the grant of a patent on the basis of this application.

Signature(s) Novagraaf Patents Limited
NOVAGRAAF PATENTS LIMITED
Date 30/09/2003

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DEWATERING TREATMENT SYSTEM AND METHOD

The invention relates to a system and method for the treatment of sludges, slurries, pulps and other materials comprising a disbursement of particles in a liquid to reduce the liquid content thereof, and in particular to a system and method for the dewatering of sewage sludge.

Industrial processes result in the generation of large quantities of sludges, slurries, pulps and other materials where there arises a requirement to reduce water content. For example sewage treatment processes require treatment of sewage sludge. Typically these materials might have an initial solid content of 0.01 to 10%. It is apparent therefore that this material can be reduced significantly in volume if the solid content can be increased by dewatering.

Current methods used to dewater sludge and other materials include continuous processes such as belt presses and batch processes such as filter presses. These systems operate by providing a positive pressure to the waste material contained within the filter plates or between the belts of the belt press using mechanical or hydraulic means. By way of example, discussions below concentrates on sewage dewatering systems, but the invention is of general applicability to the removal of water and other liquids from all materials above.

The applied pressure induces hydraulic drainage in accordance with Darcy's law (i.e. the quantity of water/fluid removed is a function of the pressure applied, the hydraulic gradient, the surface area and the hydraulic conductivity of the material). Drainage is effected through a drainage medium which typically takes the form of a polymeric belt or sheet comprised as, or as a part

of, one or more walls of the pressure cell or one or more of the belts of the belt press as the case may be. Drainage can be operated as a batch process, but belt press processes are often preferred as they can be made continuous, with the belt press disposed as a sludge conduit whereby relatively low solids content sludge is input at one end in a fully watered state, passed along under progressively increasing pressure (conveniently by reducing the distance between the belts) and delivered at an output in a partly dewatered state at the other end. Pressure is usually applied by rollers. Belt arrangements may be linear or geometrically more complex.

The sludge may be chemically pre-treated to enhance the dewatering effect, for example by the addition of organic or inorganic flocculants, coagulants or the like.

The principal limitation of the current technology is that as the drainage increases the hydraulic conductivity of the waste material decreases and an ever-increasing external pressure needs to be applied to maintain drainage. This places a practical limitation on the extent to which the sludge can be dewatered using a practical system relying on pressure alone. For example in practice the maximum degree of dewatering which can typically be achieved in conventional sewage sludge belt presses is such as to produce an output dewatered sludge with a percentage of dry solids varying between 15 and 20%.

Whilst this is appreciably more concentrated than the initial fully-water sludge the liquid content remains significant. It remains desirable to reduce this still further.

It is an object of the present invention to mitigate some or all of the above limitations.

It is a particular object of the present invention to provide an apparatus and method for the removal of liquid from a sludge slurry, pulp or other material based on current, pressure-based apparatus and methods, but offering enhanced efficiency of liquid removal.

It is a particular object of the present invention to provide an adaptation to existing pressure-based apparatus and methods for the dewatering of sewage sludge which enhances the dewatering process.

Thus according to the invention in a first aspect there is provided an apparatus for reducing the liquid content of a material comprising a particulate/liquid dispersion, the apparatus comprising containment means to contain the material, and means to apply pressure to the contained material therein, the containment means being partly defined by a filtration membrane permeable to the liquid but impermeable to at least some and more preferably substantially all of the solids contained within the material, wherein the filtration membrane comprises a textile or other synthetic material at least in part associated with a first electrode so as to constitute where so associated a conducting electrokinetic textile or other synthetic material and at least one second electrode is provided remotely spaced therefrom in contact with the material to allow application of a potential difference across the material.

In accordance with the invention the apparatus still applies pressure in the conventional manner to effect a degree of drainage in the manner above described. In this respect the filter membrane serves as a conventional drainage medium as above described. However, the filtration membrane is, at least in one or more areas thereof, provided in association with a conductive material so as to serve in use as a conducting electrokinetic textile or other synthetic material. This, together with the presence of the second electrode, allows a voltage to be applied across the sludge. The resultant electro-osmotic

effect acts in concert with the drainage effect produced by the mechanically applied pressure to enhance the dewatering.

The filter membrane is described as a textile or synthetic which in this context means a sheet-like material having a primarily polymeric base structure. The textile may be woven, knitted, needle-punched, non-woven or otherwise fabricated. The textile may include conducting elements, which may be metallic, in a composite material composition, but is not fabricated entirely or primarily from metal alone. Particularly suitable materials will include those materials known for use as conducting geosynthetic materials.

The ability of electrokinetic phenomena to move water, charged particles and free ions through fine-grained low permeability substrate is established. There are five principal electrokinetic phenomena: streaming potential, migration potential, electro-osmosis, ion migration and electrophoresis. The last three are concerned with the transport mechanisms developed upon application of an electrical field across a substrate mass and are relevant to the present invention, which exploits elecro-osmosis in particular.

To generate an electro-osmotic effect, an electrical field is applied across a substrate mass. Cations are attracted to the cathode and anions to the anode. The three transport mechanisms are explained below. In electro-osmosis, as the ions migrate they carry their hydration water with them and exert a frictional force on the water around them. Hence, there is a flow of water at both the anode and the cathode. In order to maintain a charge neutrality however, there are more cations than anions in the pore fluid of the substrate containing negatively charged particles. Therefore there is usually a net flow of water to the cathode. This electro-osmotic flow depends upon the applied voltage gradient and the electro-osmotic permeability of the substrate.

In accordance with the invention, the combination of conventional pressure drainage and electro-osmotically induced drainage enhances the liquid removal process. For a given apparatus and applied pressure, advantages can be obtained both relating to the speed at which liquid is removed and relating to the maximum degree of drying which can be practically obtained. The apparatus does not require great deviation from established principles. Rather, it exploits established principles for the removal of liquid from sludge and any other material using applied pressure through a filtration membrane, but merely enhances the effect by causing the filtration membrane, or at least parts thereof, to function during use as a conducting electrokinetic textile or other material. It has been found that using electro-osmosis can significantly enhance the treatment of the material using otherwise conventional technology.

In the preferred case, an electrokinetic geosynthetic material is used. This can provide all the functions of a conventional geosynthetic material (i.e. drainage, filtration and reinforcement) as well as acting as an electrode.

The key to the invention is that the textile or like synthetic material making up the filtration membrane is able in use to function, at least over a part of the area thereof, as an electrokinetic textile/synthetic material. It will be apparent that this can be achieved in two ways.

First, it can be effected by provision of a separate conductor so disposed within the apparatus as to be caused during use to come into contact with the filtration membrane material over at least a part of the area thereof.

In the alternative, it will in many instances be more convenient if the filtration membrane is inherently a conducting material, or is at least partly comprised of such a material, in that the material of the filtration membrane is inherently

conducting or integrally incorporates conductive material into its structure. In particular, the material of the filtration membrane is a geosynthetic material. It will be appreciated that for many of the apparatus geometries discussed below by way of example exploiting one of the above principles, it would be a trivial matter to apply the alternative principle.

The entire filtration membrane may integrally comprise conducting electrokinetic textile/synthetic material. Conveniently however, the filtration membrane preferably comprises a plurality of discrete conductive regions. This allows applied current in use to be limited to discrete areas as required.

The present invention is suited to any pressure-based sludge or other material dewatering treatment system, whether batch-operating, or continuous. However its particular advantages are conferred in relation to continuous processes, such as sludge belt presses. Accordingly, in a preferred embodiment of the invention, the apparatus is a sludge belt press wherein at least one of the belts is associated with a conductor for at least a part of the length thereof, and in particular is at least partly comprised of conducting electrokinetic textile/synthetic for example geosynthetic (EKG) as above described.

That is to say, the apparatus as above described is configured such that the containment means defines a conduit with a sludge input, a sludge output, means to apply pressure therealong, especially steadily increasing with distance from the input to the output, and a filtration membrane substantially along the length thereof, the filtration membrane being associated with a conductor for at least a part of the length thereof, and in particular being at least partly comprised of a conducting geosynthetic material, and at least one further electrode substantially along the length of the conduit and remotely

spaced from the conductor to allow an application of potential difference across the sludge within the conduit.

A potential difference is applied along such part of the length of the conduit as it is desired for an electrokinetic as well as a hydraulic dewatering pressure to be applied. This may be essentially along the length of the conduit to ensure that essentially along its entire length an electrokinetic as well as a hydraulic dewatering pressure is being applied. In many practical applications it will be preferred to apply the potential difference only to a part of the conduit, in particular towards the downstream portion, such that initial dewatering is essentially hydraulic and dewatering is electrokinetically enhanced further downstream.

Where it is desired to apply a potential difference across the sludge in a region relating to only a part of the filtration membrane, this may be achieved in that a conductor is associated only with that part of the filtration membrane. Alternatively, conductors may be associated with the membrane across substantially its entire area, for example in a plurality of discrete regions, but only electrically supplied in the desired region. Where the apparatus is a continuous belt apparatus, and more particularly where the belt comprises EKG material, the latter approach may be preferred.

It will be understood that none of the foregoing requires the area associated with the conductor or the second electrode to be continuous in the region where a potential difference is to be applied. Either or both may instead be disposed as a discontinuous plural array provided that the arrangement permits the application of the necessary potential difference across the sludge or other material to be dewatered in the area of the filtration membrane to generate the necessary electrokinetic effect.

As indicated, the filtration membrane is preferably integrally conducting and in particular comprises a conducting electrokinetic geosynthetic material (EKG). The principles of conducting electrokinetic geosynthetic materials have been established, and were for example set out in International Patent application number WO95/21965 to Jones *et al* incorporated herein by reference.

The EKG material may have any suitable composition to give conductive properties. For example, the conductive geosynthetic material may comprise a generally inherently non-conductive geosynthetic material in association with at least one conducting element to produce a composite conducting geosynthetic material. Alternatively, the geosynthetic material may be inherently conducting, for example being loaded with conducting particles, and for example comprising polymeric material loaded with carbon. Such inherently conducting geosynthetic material may additionally be associated with at least one separate conducting element, to provide a composite conducting geosynthetic.

In a preferred embodiment, the electrokinetic belt or medium (EKG)comprises a woven or non-woven polymeric and for example geosynthetic material incorporating a plurality of elongate conducting elements therewithin, in particular in one or more parallel arrays. The conducting elements may for example be threaded through or woven into the basic geosynthetic material. Two or more arrays may be disposed in different directions to form a network structure. The filtration membrane will generally comprise sheet material, and the elongate conducting elements will be disposed generally laterally therewithin. Where the geosynthetic material constitutes a belt or part thereof for a belt press type device such arrays may lie generally parallel to, perpendicular to, or angled to the longitudinal direction of the belt.

A possible electrically conducting geosynthetic material could simply comprise a conventional geosynthetic material which has woven therein, or threaded therethrough, electrically conducting filaments or threads which may be single or multi-stranded. The filaments or threads comprise conducting elements. In the instance where the electrically conducting geosynthetic is woven, electrically conducting threads or filaments may be intertwined with or enmeshed within conventional geosynthetic materials and in the instance where the electrically conducting geosynthetic is provided in a threaded form any preselected number of passages of thread through the material may be made according to a user's requirement.

The electrokinetic geosynthetic thus combines a role as an electrode driving the electro-osmotic enhancement of the drainage process with a means of providing hydraulic pressure and acting as a drainage/filter medium in a conventional filtration membrane role. It will be apparent that many of these advantages will also be relevant to the second electrode. According in a preferred embodiment, the second electrode is also a conducting geosynthetic material.

The electrodes provided in accordance with the invention do not corrode. Previous attempts at introducing electrokinetic processes to belt press and other sewage dewatering technology have frequently failed due to the rapid deterioration of the electrodes. By contrast, there is a body of established EKG technology which will provide materials able to resist environmental degradation

The invention offers particular advantages in relation to belt presses. In a normal belt press the belts move closer together as drainage occurs. This narrowing of the distance between the belts (electrodes) increases the potential gradient in the process without the need to increase the voltage applied. As a

result, as the material dries out the electrokinetic force applied increases automatically. This is in direct contrast to conventional hydraulic dewatering. In normal hydraulic dewatering processes as the % dry solids increases the hydraulic permeability decreases and dewatering becomes more difficult. In conventional hydraulic dewatering the maximum pressure applied is when the belts pass over the rollers. Away from the rollers the pressure relaxes, as the belts are able to move apart a small amount. Because of the nature of particulate materials only a small movement is required to effect a major reduction in the effective hydraulic pressure. In the case of electro-osmotically applied pressure the small increase in the distance between the belts has a negligible effect on the electrokinetic force.

The normal distance apart of the belts in a belt press is typically 50 mm reducing to 20 mm or less as the process proceeds. Potential voltage gradients in the range 600 to 2000 V/m or higher can be generated across the belts by applying a direct voltage of 30 Volts. As the voltage is low the process is inherently safe.

An unexpected benefit in using an EKG material to form a belt press is that a major reduction in pathogens can occur in the sludge being treated. Studies on sewage sludge cake have shown a 6-log reduction in pathogens. The reduction in pathogens can be caused by a number of factors including: (a) chemical degradation of the pathogen cell walls in adverse pH conditions (especially high pH around the cathode); (b) surface charges on the cell walls of bacteria (e.g. E. coli.) give the particles a high mobility under an electrical field; (c) an increase in temperature of the sludge. The result is that pathogens are rapidly transported to the cathode where they are either destroyed by adverse pH or removed with the electro-osmotic flow with an additional pasteurization effect due to the increase in temperature.

Other benefits of the use of EKG materials to form the belts in a belt press include evolution of ammonia which helps to improve C: N ratios and increased biodegradability of the sludge material. In addition increased dewatering of activated sludge is promoted.

Another benefit is that only parts of the belt need to be made conductive. It can be advantageous for the edges of the opposing belts not to be conductive as this permits the opposing belts to touch without creating a short circuit.

Another benefit of using an EKG material to form the belt is that the detachment of the dewatered sludge is easier than if a metal belt is used. In addition the filter and drainage characteristics of a geosynthetic can be used and the belt can offer an element of elasticity.

EKG belts can be made of hydrophobic or hydrophilic materials this can have advantages in respect of dewatering or keeping the belts wet and therefore conductive.

Metal belts can be used in belt press dewatering systems but these have inherent weaknesses if used with electrokinetic processes including; corrosion and the release of metallic ions many of which are toxic.

EKG belts can be used to retrofit existing belt press dewatering plant to permit electrokinetic dewatering to be used.

All sewage sludges are candidates for treatment. All sewage materials studied to date have been shown to support electro-osmotic treatment.

Although much of the discussion herein has related to belt presses, EKG materials can also be used in batch process dewatering systems, the EKG

taking the place of the textile filter/drains. The benefits identified above apply equally to batch processing methods used to dewater sewage sludge and the like.

In accordance with the invention in a further aspect there is provided a method of removal of liquid from a sludge, a method comprising the steps of: containing the sludge within a containment means, which containment means is at least partially defined by a filtration membrane permeable to the liquid in the sludge but impermeable to at least some, and preferably substantially all, of the solid components of the sludge, which filtration membrane comprises a filtration material associated with a conductor element, and for example an electrically conductive geosynthetic material, to serve as a first electrode; providing a second electrode remotely spaced therefrom in contact with the sludge, applying pressure to the sludge to induce hydraulic drainage through the filtration membrane; applying a potential difference between the electrodes to induce electro-osmotic drainage through the filtration membrane.

Enhanced drainage effect is achieved by applying the pressure and the potential difference in such a manner that the hydraulic and electro-osmotic drainage effects compliment and enhance each other.

Preferably the potential difference is applied across a controlled area of the sludge only, which can be effected either by ensuring that only a controlled area is conductive or by applying a power source to only a part of the conductive area or to one or a few of a plurality of discrete conductive zones on the filtration membrane.

As will be appreciated for the reasons given in more detail above, the process is in particular a continuous belt process, wherein the containment means is provided as a conduit with a sludge input for sludge having full liquid content

and a sludge output for sludge where the liquid conduit has been reduced and a means to apply pressure there along, especially increasing pressure, for example by reducing cross sectional area to an appropriate extent; and feeding sludge into the input, causing the sludge to travel there along, applying pressure and potential difference there across as above described to reduce the liquid content by simultaneous application of hydraulic and electro-osmotic drainage effects, and removing the sludge at the output.

In particular the method is a method for the treatment of sewage sludge by dewatering.

The invention requires little modification to the underlying construction of dewatering cells and belt presses. Existing designs can readily be employed, with a conductive filter membrane fitted or an existing filter membrane caused to become conductive in situ by associating in situ with a conductor element. In a further aspect the invention comprises a method of modifying a conventional dewatering apparatus such as a belt press by creating a conductive filter membrane so that the apparatus performs as the invention hereinbefore described, and further comprises a dewatering apparatus such as a belt press which has been so modified.

The invention will now be described by way of example only with reference to figures 1 to 5 in which:

Figures 1 to 3 are representations of suitable materials for a filtration membrane in accordance with the invention;

Figure 4 is a cross-section of a possible belt press arrangement employing both conventional hydraulic drainage principles and the electrokinetic principles of the present invention.;

Figure 5 is a side view and cross-section of an alternative possible belt press arrangement.

Figures 1 to 3 illustrate sheet materials suitable for use in accordance with the invention, for example as a belt in a belt press or as a filtration sheet for a cell for a batch system. In each case a woven sheet or belt 1 is formed from a base of woven polymeric material 2, to that extent comprising a conventional geotextile providing a drainage and filtration function. Suitable materials will include polyester polypropylene and polyamides.

A parallel array of elongate conductors is provided in association with the sheet or belt 1. Suitable materials will include carbon, coated metals and conductive polymers. Two alternative arrangements are shown. In figure 1a a first array of elongate conductors 3a is disposed on an upper surface of the sheet or belt 1 and a second array of elongate conductors (not shown) is disposed on a lower surface. In figure 1b a single array of elongate conductors 3b is disposed within the sheet or belt 1.

The drainage and filtration material is conveniently a belt for a belt press. The belt press is formed with conducting belt elements being provided with conductors in or on the surface of the belt. Figure 2 illustrates example conductor geometries. In figure 2a a woven sheet or belt 11 is formed from a base of woven polymeric material 12 into which is incorporated a parallel array of elongate conductors 13, lying parallel to the intended direction of travel of the belt in use (as represented by the arrow D). In figure 2b a parallel array of elongate conductors 14 lies generally perpendicular to the intended direction of travel of the belt in use. In figure 2c the elongate conductors 15 form a two-dimension network by being angled relative to the intended direction of travel of the belt in use.

It can be an advantage in some applications for only a section of the belt to be conductive at any one time. In a typical sludge dewatering system, at the beginning of the belt press dewatering process the belts are around 50 mm apart and the main dewatering process is hydraulic flow with limited need or potential for electro-osmotic enhancement. As the level of water in the treated material decreases the hydraulic permeability decreases, the rate of dewatering decreases and it can be efficient to apply the electro-osmotic pressure at this later point in the dewatering cycle. Using this approach can be more effective as the opposing belts are then at a reduced distance apart and the voltage gradient is optimised. In this case, the belt is so arranged, and in particular the conducting elements so disposed, that a plurality of discrete, electrically isolated areas lie longitudinally along the belt.

Disposing an array of conducting elements in the perpendicular direction of figure 2b is one way that this can be achieved. It allows a belt to be formed wherein each conducting element projects beyond a belt edge to provide a connection means for application of electrical power. This is illustrated in figure 3. The successive projections 16 provide a simple way to apply potential difference across one or more selected zones along the length of the belt. The principle of providing laterally projecting connectors projecting beyond a belt edge but conductivily linked to conducting elements therewithin can be generally applied to create conduction zones provided that those conduction zones are electrically isolatable as discrete conducting regions along the length of the belt. The use of transverse conducting elements as illustrated in figure 3 is a simple way this can be effected.

Figure 4 shows a further advantage of this system, illustrated as a cross-section through a sludge zone in a simple two-belt press. Sludge 21 is retained between a top belt 22 and a bottom belt 27. The conductor 23 of the upper

belt projects beyond the edge, the projection 24 providing a contact for an external electrical power source. The conductor 28 of the lower belt projects beyond the opposite edge, the projection 29 again providing a contact for an external electrical power source. Each conductive element may also be curtailed on the opposite edge of the belt to the one where it projects, as is shown in the example. In this way, a non-conductive zone can be created at the edges of the belts, which can come into contact, avoiding shorting.

An existing belt can be transformed easily into an EKG belt by attaching or causing a conductive element to be in intimate contact with a belt so as to act like the structure in Figure 1a. Alternatively a specially fabricated belt incorporating a conductive element can readily be retrofitted to a standard belt press. Thus, a modified belt press in accordance with the invention can be created without departing from existing principles. Similar considerations will apply to pressure cells and the like.

The conductive element does not have to be associated in fixed relationship to the belt or other filter membrane. Figure 5 gives an example of the forming of a conductive membrane by passing a moving filter material over and into intimate contact with a fixed conductor. In figure 5 sludge 31 lies between upper 32 and lower 37 belts. Fixed conductors 33, 34 create a conduction zone where they come into contact with the belts 32, 37. Only a portion of the length of the belt is made conductive, for the efficiency reasons set out above. Also, each conductor does not extend fully across the width of the belt in that region, again creating a non-conductive zone at the edges of the belts to avoid shorting.

The invention thus provides an admirable way to modify existing dewatering apparatus which rely solely on hydraulic dewatering or to create new apparatus based in part on and exploiting existing hydraulic dewatering

principles so as to exploit the enhanced efficiency available through using electrokinetic effects in a suitably controlled manner.

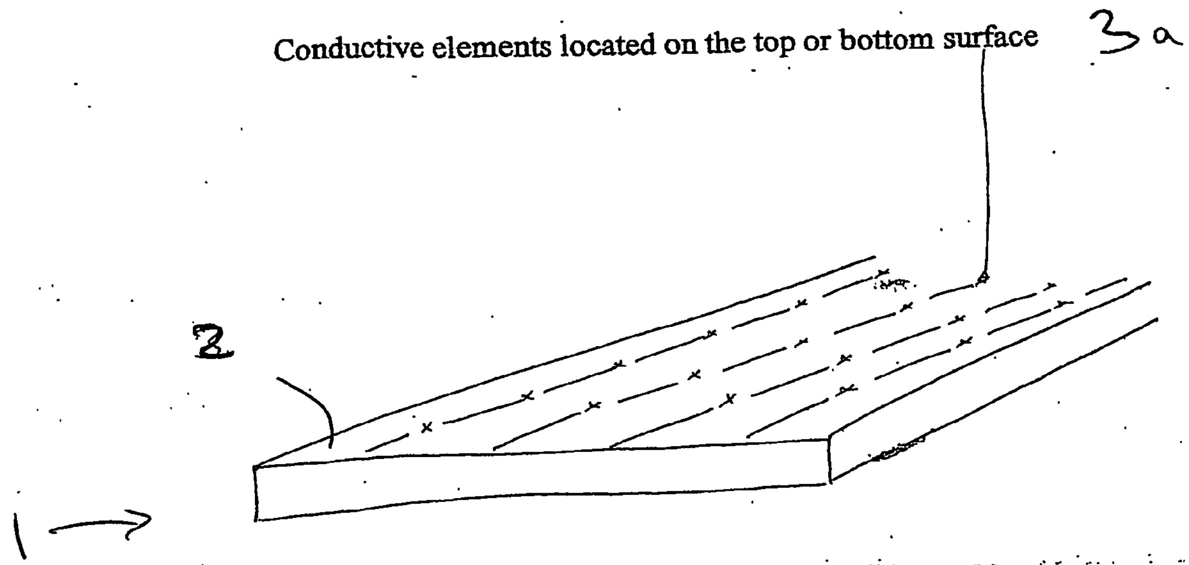


Figure 1(a)

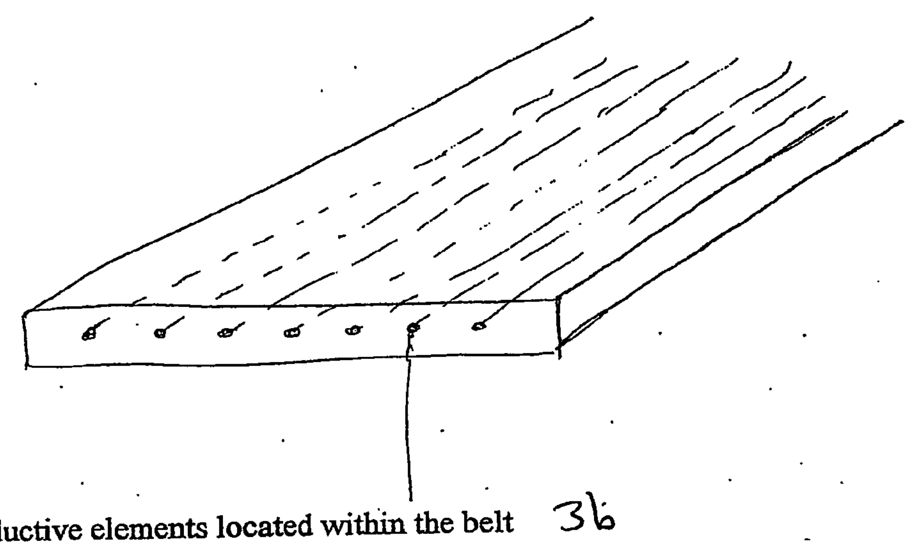


Figure 1(b)

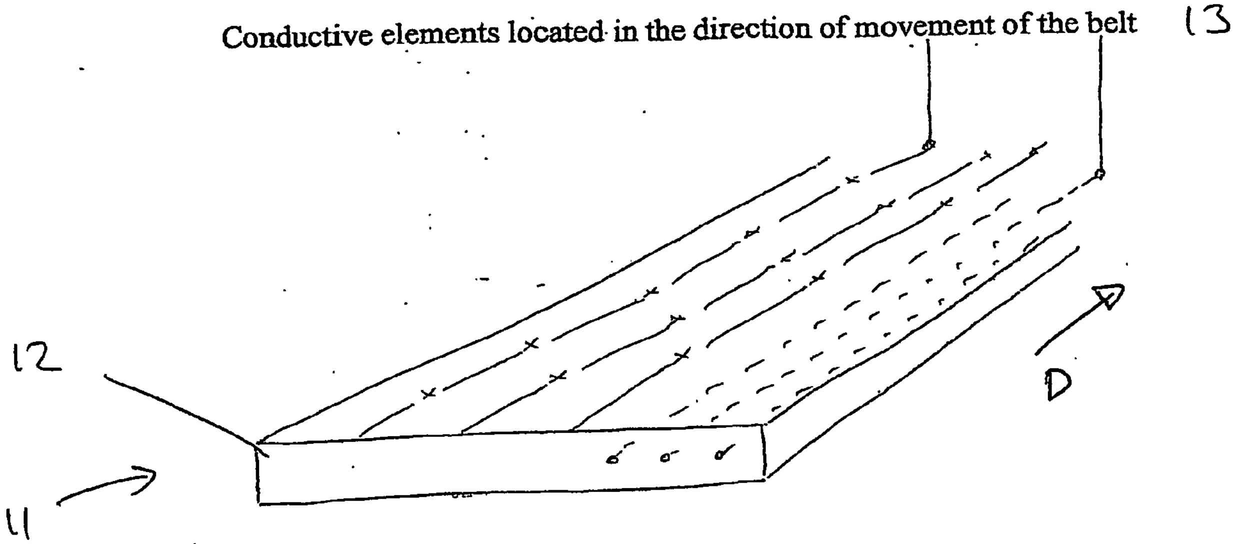


Figure 2(a)

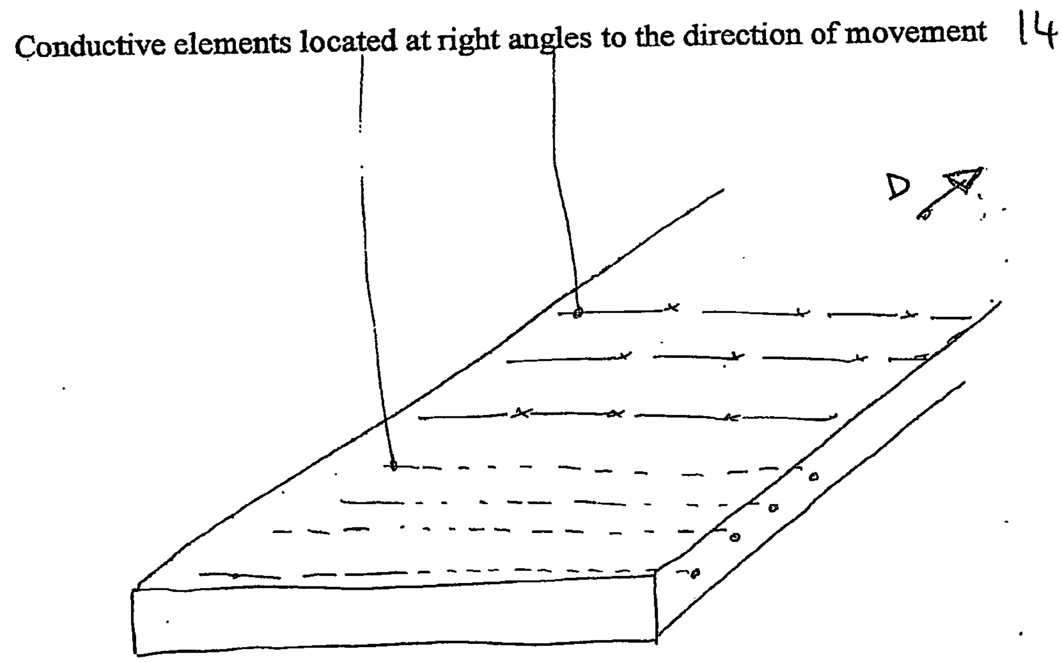


Figure 2(b)

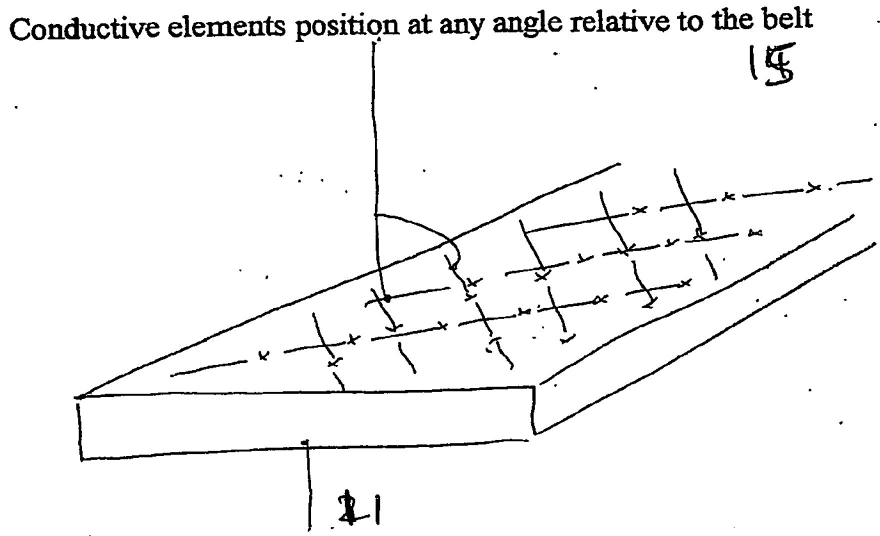

Conductive elements position at any angle relative to the belt
15
21

Figure 2(c)

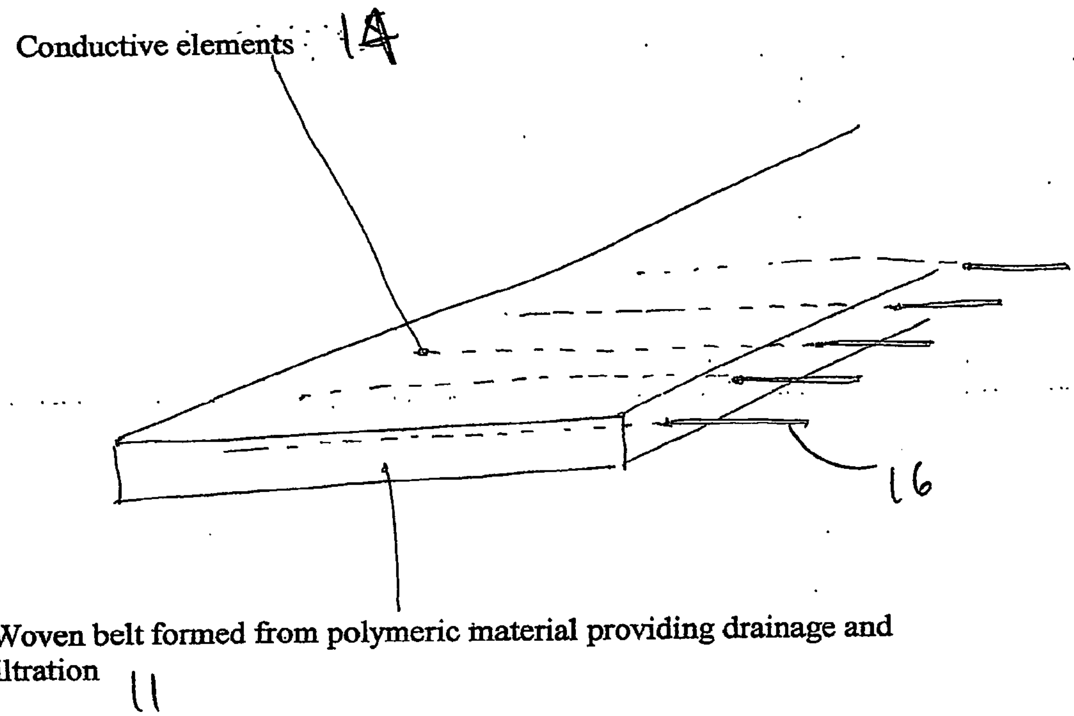


Figure 3 Sketch showing conductive elements extending beyond the edge of the belt

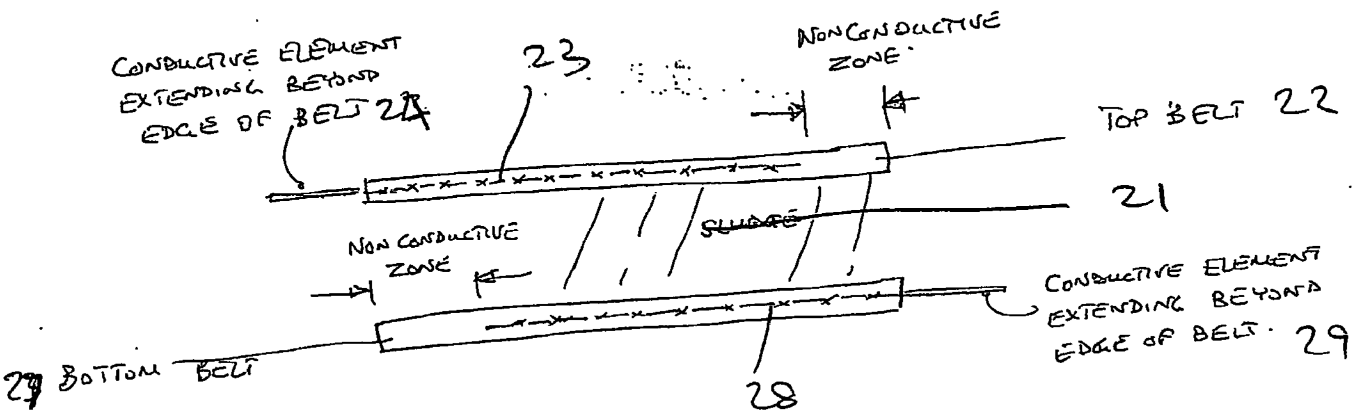
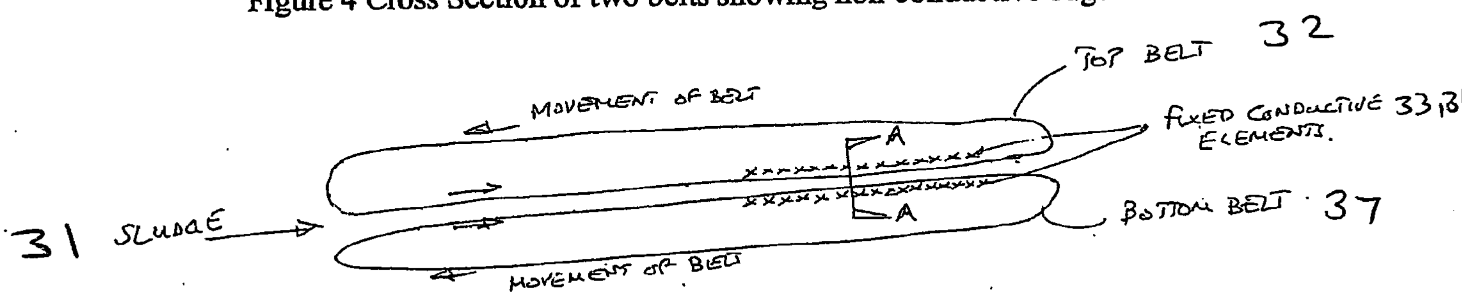
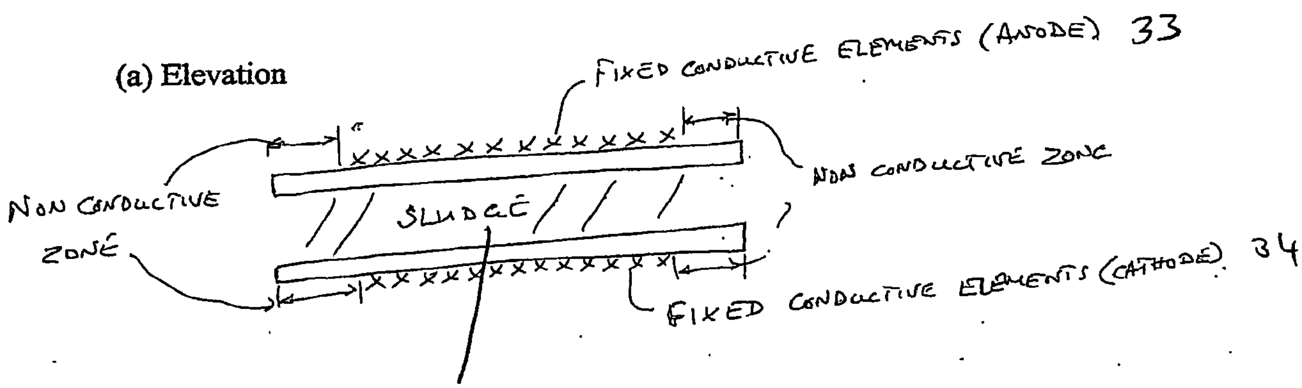


Figure 4 Cross Section of two belts showing non-conductive edges



(a) Elevation



(b) Cross section A-A 31

Figure 5 EKG Belt formed using fixed conductive elements